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February 20, 1973

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MEMORANDUM TO: J. R. Harbison
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Chairman, Research Committee

SUBJECT: Research Report No. 357; "Evaluation of the High-Accident Location Spot-Improvement Program in Kentucky;" KYP-72-40, HPR-1(8), Part III.

For the first time, we have been able to evaluate the benefits in terms of accident reductions derived from a large number of low-cost, spot, safety improvements. The enabling programs were:

1. The Traffic Division's High-Accident Site Identification Computer Program
2. Accident Data Storage Files (Computer tapes, from 1967).
3. The High-Accident Site Investigating Teams' records of sites, recommendations, improvements and costs (file maintained by Traffic Division).

About 85 to 90% of the sites "flagged" by the computer program were found, upon review of the accident reports to be spurious -- that is, the accidents fit no pattern or otherwise seemed unrelated to a feature of the roadway. This means that the computer method of identifying high-accident sites (3 accidents in 12 months) currently used is only a cursory sorting. About 65% of the sites investigated warranted some type of improvement. The evaluation or analysis of benefits gained from the program is based only on sites investigated in the field. In one respect, the analysis validates the capabilities of the investigating team to discern corrective measures; but, moreover, it demonstrates that a high degree of success was achieved in reducing accidents and the attendant cost of accidents in comparison to the time and effort expended.

I am priviledged, indeed, to submit Mr. Agent's report in behalf of the spot-improvement program.

An additional study has been undertaken to develop a more efficient criterion for identifying high-accident sites at the first stage.

Respectfully submitted,

Jas. H. Havens

Jas. H. Havens
Director of Research

JHH:dw
Attachment
cc's Research Committee

Executive Summary

EVALUATION OF THE HIGH-ACCIDENT LOCATION SPOT-IMPROVEMENT PROGRAM IN KENTUCKY

by

K. R. Agent

Since 1968, the Kentucky Department of Highways has had a program which involves minor safety improvements at high-accident locations. A high-accident location has been defined as a location (0.1 mile in length) which has had three or more accidents during the previous 12-month period. A computer printout containing all such locations is prepared each month. After thorough screening to eliminate locations where accidents occurred in a random and unrelated manner, locations are investigated in the field and recommendations are made and implemented. The objective of this study was to evaluate the overall effectiveness of the spot-improvement program in reducing accidents.

To perform this "before' and "after' accident study, the accident history for each location was obtained for the period January 1, 1967 to June 30, 1972. Accidents were summarized by two alternate methods -- a 0.1-mile interval and a 0.3-mile interval. Accidents at all locations were summarized for one-year periods both before and after the date of reference, taken as the improvement date for locations were improvements were recommended and as the investigation date for locations where no improvements were recommended. Two-year before and after tabulations were prepared for locations whose reference date was between January 1, 1969 and June 30, 1970. Accident savings resulting from the program were calculated by two methods -- total accident cost (including indirect cost) and direct accident cost. Benefit-cost ratios for the program were then calculated for both the 0.1-mile and 0.3-mile intervals using both total cost and direct cost. Benefits were defined as the savings in accident costs, and the costs were defined as the sum of the cost of improvements and the administrative cost. Benefits were attributable only to the first-year after period, which results in a very conservative estimate. The change in the accident severity between the before and after periods was also compared.

The first comparison made was between the periods one-year before and one-year after the reference date. The number of accidents of all types were greatly reduced in the after period. The reduction in total number of accidents was found to be 43 percent and 59 percent for the 0.3-mile and 0.1-mile segments, respectively. This accident reduction was found to be statistically significant. The benefit-cost

ratios were all greater than 1.0. It was also found that there was no significant difference in the before and after accident severity.

Next, figures were drawn to determine the difference between the before-and-after experience of locations where no improvements were made and those where improvements were implemented. These figures indicated that the reduction in accidents from the first-year before the reference data to the first-year after was approximately the same for the locations where no improvements were made as for those locations which were improved. The large number of accidents in the first-year before period resulted from the fact that the locations were identified as high-accident locations, i.e. a high number of accidents occurred during the preceeding 12-month period. The method of selecting these locations has resulted in the selection of some locations where the high number of accidents was largely due to random events. The significant comparison was of the second-year before and first-year after data. For the locations where no improvements were recommended, the number of accidents in these two time periods were very similar; but there was a reduction in accidents during the first-year after period for locations which had been improved. Therefore, the reliable indicator of the "before" accident experience is the second-year before accident data.

From the preceeding discussion, it was decided to use the second-year before the reference date as the "before" period and the first-year after as the "after" period. This analysis showed that accidents were reduced by a large percentage in the 'after" period. The reduction in total number of accidents was found to be 25 percent and 31 percent for the 0.3-mile and 0.1-mile segments, respectively. This accident reduction was found to be statistically significant. Benefit-cost ratios were found to be greater than 1.0 except in the case where direct costs were used for a 0.1-mile segment. However, in 18 months, this benefit-cost ratio would be greater than 1.0. The accident severity was again found to be unchanged from the "before" to the "after" period.

The following conclusions were drawn from the analyses of the before and after accident data:

1. The spot-improvement program has resulted in a significant reduction in accidents at high-accident sites.
2. The cost of this program has been a good investment as denoted by the favorable benefit-cost ratios.
3. Severity of the accidents did not change significantly as a result of the spot-improvement program.
4. In this type of study, second-year before accident data was found to be more representative of the long-term accident experience than the first-year before data.

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Evaluation of the High-Accident Location Spot-Improvement Program in Kentucky		5. Report Date February 1973 6. Performing Organization Code
7. Author(s) Kenneth R. Agent		8. Performing Organization Report No. 357
9. Performing Organization Name and Address Division of Research Kentucky Department of Highways 533 South Limestone Lexington, Kentucky 40508		10. Work Unit No. 11. Contract or Grant No. ~~HPR~~ KYP-72-40 13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address		Final ~~Interim~~ 14. Sponsoring Agency Code

15. Supplementary Notes

~~Prepared in cooperation with the US Department of Transportation, Federal Highway Administration~~

Study Title: Evaluation of the High-Accident Location Spot-Improvement Program in Kentucky

16. Abstract

The purpose of this study was to determine the overall effectiveness of the spot-improvement program in Kentucky. Safety improvements have been made at 349 locations (through June 30, 1971) since the program started in 1968. Before-and-after accident summaries were made at these locations as well as locations where the investigation resulted in no recommendations for improvements. It was found that the second-year before accident data was more representative of long-term accident experience than the first-year before data. From the analyses, it was found that the spot-improvement program has resulted in a significant reduction in accidents at high-accident location sites. The favorable benefit-cost ratios which were obtained indicated the cost of the program has been a good investment. Severity of the accidents was found to have not changed significantly.

17. Key Words	18. Distribution Statement
High-Accident Location Safety Improvement Severity Index Benefit-Cost Ratio	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-69)

Research Report
357

EVALUATION OF THE HIGH-ACCIDENT LOCATION SPOT-IMPROVEMENT PROGRAM IN KENTUCKY

KYP-72-40; HPR-1(8), Part III

by

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DEPARTMENT OF HIGHWAYS
Commonwealth of Kentucky

February 1973

INTRODUCTION

In an effort to reduce the large number of motor vehicle accidents occurring annually throughout the United States, many safety improvement programs have been initiated. One such program, in operation within the Kentucky Department of Highways since 1968, involves minor safety improvements at high-accident locations. Improvements made under this program consist of installation or modification of traffic control devices and minor construction and maintenance.

This program has been in effect for over five years, and a large number of spot improvements have been made. The purpose of this study is to determine the overall effectiveness of the spot-improvement program in Kentucky. It is supported by one of the recommendations of the Special AASHO Committee on Traffic Safety *(1)*; that is, to make follow-up studies for evaluating the effectiveness of corrective measures undertaken in spot-improvement programs.

Spot-Improvement Program in Kentucky

The program operates in the following manner. Each month, a computer printout is prepared indicating all locations where three or more accidents occurred during the previous 12-month period. The source of this list is a statewide accident file maintained by the Department of Public Safety. This file contains a record of all accidents investigated and reported by the state police. Unfortunately, Kentucky does not have uniform accident reporting on a statewide basis; thus, only state-police-reported accidents are available to be used in this program. The accidents in most urban areas are not investigated by state police; consequently, nearly all of the improvements being made are in rural areas. State police reports show the location of each accident – estimated to the nearest 0.1 mile from a milepost marker.

The monthly list of high accident locations together with copies of all accident reports for these locations are screened by highway engineers in the central office and districts to determine which locations should be investigated in the field. Field inspections are not made at locations where, in the opinion of the engineer, the 12-month accident history is unrelated to site deficiencies. Locations which have been investigated previously and corrected to the point of major reconstruction are not revisited. At the present time, only approximately ten percent of the locations in the monthly computer list are investigated in the field.

Each location warranting a field inspection is assigned to a multidisciplinary team. This team, composed of traffic engineers, maintenance engineers, and police personnel, investigates the location and formulates its recommendations. Recommended improvements are then implemented through the spot-improvement program.

Evaluations Conducted by Other States

Most states now have spot-improvement programs similar to the one in Kentucky in that they involve the identification of high-accident locations, and consequently, the addition of safety improvements. Many of these states have conducted evaluations to determine the effect these improvements have had on accident experience at these locations. Different indicators have been used to evaluate the programs. From one such evaluation, the Ohio Department of Highways *(2)* concluded that improvements enacted under their program were effective in increasing the safety at high-frequency locations on their Rural State Highway System. The conclusion was based on the decrease in severity following installation of the improvements. This reduction was based on a one-year before-and-after study and the comparison of the percent reduction in injury accidents for the improved locations and locations where no improvements were recommended. Evaluations of the spot-improvement programs in Virginia, Wisconsin, and California have used two-year before-and-after periods as the data base *(3, 4)*. The chi-square test *(2, 5)* and the Poisson test *(6)* are two tests used to determine the statistical significance of the findings. The methods of evaluating the change in the total number of accidents from the before to the after period have involved determining the percent change in total accidents as well as the percent change in the accident rate. In evaluating the change in severity of accidents, some investigators relied on the percent change in the number of fatal and injury accidents *(2, 3, 4)* while others used a severity index *(5, 6)*. Cost of improvements in relation to the resulting savings were used as a basis to determine if the program had been a good investment *(3, 5)*. Several studies classified the type of improvement and evaluated the effectiveness of each *(3, 4, 5)*.

STUDY PROCEDURES

All locations in the spot-improvement program investigated between January 1, 1968 and June 30, 1971, were included in this evaluation. Locations, dates of investigations, recommendations of the field team, completion dates, and costs of any improvements were obtained from a computer printout. Accident data were obtained for the period from January 1, 1967 to June 30, 1972; at least one year of accident data before and after each date of improvement was desired.

Since high-accident locations were identified to the nearest 0.1 mile, accidents reported as occurring at the 0.1-mile interval were summarized. Also, to encompass the site more fully, accidents occurring within a 0.3-mile interval, centered around the 0.1-mile segment, were also summarized. The second method provides for some errors in estimating the distance of the accident location from the nearest milepost marker and gives some consideration to the possible existence of a high-accident zone. Evaluations were made by each of the methods.

Accidents at all locations were summarized for one-year periods both before and after the date of reference. For locations where an improvement was made, the reference date was taken as the improvement completion date; where no improvements were recommended, the reference date was taken as the date of investigation. For locations having reference dates between January 1, 1969 and June 30, 1970, data for two years before and two years after were also summarized.

Effectiveness of the spot-improvement program was evaluated using the following three indicators:

1. Change in number of accidents between the before and after periods,
2. Benefit-cost ratio, and
3. Change in the severity index between the before and after periods.

Statistical tests were used in evaluating Indicators 1 and 3.

Alternate means for estimating accident costs were also employed. In the first and more conservative analyses, only direct costs were used. In the second and perhaps more realistic analyses, total accident costs, including both direct and indirect components, were used. The direct costs include property damage, medical costs, loss of use of vehicle, value of work time lost, legal costs and other items. The indirect component of accident cost consists mainly of losses of future earnings. The following total accident costs for 1970, as determined by the National Safety Council *(7)*, were used:

Fatality	\$45,000 per fatality
Non-fatal injury	\$ 2,700 per injury
Property damage accident (PDO)	\$400 per accident

The following direct accident costs, as derived in APPENDIX A, were used:

Fatal accident	\$ 9,880 per accident
A-type injury accident	\$4,570 per accident
B-type injury accident	\$2,635 per accident
C-type injury accident	\$1,525 per accident
Property damage accident	\$585[a] per accident

APPENDIX A also contains a detailed description and derivation of the severity index (SI). The severity index indicates the average severity of accidents occurring at a particular location. It is computed by dividing the number of equivalent property-damage-only (EPDO) accidents by the total accidents. The number of EPDO accidents is a weighted total in which fatal and injury accidents are weighted using accident cost comparisons.

[a]This figure is considerably larger than the corresponding figure from the National Safety Council since basically all PDO accidents used in the direct-cost calculations were rural accidents and the costs of rural accidents are larger than urban accidents. The National Safety Council costs are based on a more even distribution of rural and urban accidents.

Several improved locations across the state were selected for detailed illustration. "Before" and "after" collision diagrams were drawn for each location to show the manner in which improvements affected accident experience. Photographs of the locations were also made. An inventory of the spot-improvement program was also completed. A summary was made of the number of locations which were investigated and the number of investigations which led to improvements. The total cost of improvements was summarized along with the number of times each type of improvement measure was used.

Locations where improvements had been made were classified into four very broad types, and the effectiveness of improvements for each type of site was compared.

RESULTS

Table 1 summarizes locations investigated under the spot-improvement program during the period from January 1, 1968 through June 30, 1971. A total of 578 individual locations were investigated during this period. Also, 35 investigations were made at locations which had been investigated previously. Table 1 shows that a majority of the investigations resulted in recommendation and completion of improvements.

One Year Before-and-After Comparisons

Table 2 summarizes accident data for those locations where improvements were recommended and completed. The numbers and types of accidents are given for the one-year periods immediately preceding and immediately following the dates of completion of the improvements. The number of accidents of all types were greatly reduced in the after period. The reduction in total number of accidents was found to be 43 percent and 59 percent for the 0.3-mile and 0.1-mile segments, respectively. Referring to Figure B-1 in APPENDIX B, it is readily apparent that these reductions in accidents are statistically significant at the 0.05 level using the chi square test. Thus, on the basis of one-year before and one-year after comparisons, the spot-improvement program was proven to have been highly effective. It was also found, as had been anticipated, that the percentage reductions in accidents were greater for the 0.1-mile segments than for the 0.3-mile segments. As the distance interval increases, the influence of a hazardous site or location generally diminishes.

Benefit-cost ratios were also computed. Benefits were defined as a reduction in accident costs, i.e. "before" and "after" comparisons. Accident costs were based alternately on the total costs, including indirect cost, and on direct cost only. The cost component of the benefit-cost ratio was defined as the sum of the improvement costs and the administrative costs. Improvement costs were available from

TABLE I

SUMMARY OF LOCATIONS INVESTIGATED FROM JANUARY 1, 1968 THROUGH JUNE 30, 1971

RESULT OF INVESTIGATION	NUMBER OF LOCATIONS	PERCENTAGE OF LOCATIONS	NUMBER OF INVESTIGATIONS
Improvements Recommended and Completed	349	60.4	366
No Improvements Recommended	207	35.8	225
Improvements Recommended But Not Completed	22	3.8	22
Total	578[a]	100.0	613

[a]There was a total of 613 investigations made at these 578 locations.

TABLE 2

ACCIDENT SUMMARY FOR LOCATIONS WHERE IMPROVEMENTS WERE MADE
(Completion Date Between January 1, 1968 and June 30, 1971)

TYPE OF ACCIDENT OR INJURY	0.3-MILE SEGMENTS			0.1-MILE SEGMENTS		
	FIRST-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD	PERCENT REDUCTION	FIRST-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD	PERCENT REDUCTION
Accidents						
PDO	1382	787	43.1	817	335	59.0
A-Type[a]	277	144	48.0	165	72	56.3
B-Type	187	121	35.3	115	44	61.7
C-Type	182	117	35.7	113	52	54.0
Fatal (K-Type)	52	19	63.5	34	9	73.5
Total	2080	1188	42.9	1244	512	58.8
Injuries						
A-Type	439	225	48.7	285	116	59.3
B-Type	394	253	35.8	250	109	56.4
C-Type	398	242	39.2	249	108	56.6
Total	1231	720	41.5	784	333	57.5
Fatalities	60	27	55.0	37	11	70.3

[a]An injury accident is classified according to the most severe injury to any person involved.

records of the Division of Traffic. An administrative cost, based on past experience, of $500 per investigation was used. Resulting benefit-cost ratios are shown in Table 3. All ratios are much greater than 1.0 -- regarded as the minimum value needed to economically justify the safety improvement program. It is especially significant to note that benefits in these calculations accrued in the first year following completion of the improvement.

Changes in accident severity were also analyzed. One measure of accident severity is the severity index, defined as the ratio of the number of equivalent property-damage-only (EPDO) accidents to the total number of accidents (see APPENDIX A). Accident severity increases as the index increases. Table 4 indicates that only a very slight reduction in accident severity, as measured by the severity index, resulted from these improvements. Reductions were not found to be statistically significant (see APPENDIX B). Also shown in Table 4 are the percentages of various types of accidents. These data show a small reduction in the percentage of fatal accidents did occur, but the decrease was offset by a small increase in the percentage of non-fatal, injury accidents. It appears, therefore, that the safety improvement program had no significant effect on accident severity.

Peak-Year Effect in High-Accident Site Identification

Usually, only data for one-year before and one-year after are used in before-and-after accident studies. In this study, however, all locations had a high frequency of accidents in the before year; and the method of selection tends to define the "before" year as a peak accident year. Location identified as high-accident sites based on an accident experience for a short period such as a year may be truly hazardous locations reflecting physical attributes and traffic considerations at these locations or they may be simply locations which, due to a series of conditions and circumstances which might be termed random events, had an unusually severe and unrepresentative accident experience during that period. Thus, each site -- those unimproved as well as those improved -- was in a peak accident year when identified. If the peaks were the result of spurious or random occurrences, the number of accidents would tend to re-normalize in the "after" year. To evaluate this "peaking" effect, the combined accident history of the improved sites was compared to the history of the unimproved sites. Figure 1 shows the total number of accidents over a four-year period at 99 locations identified as high-accident locations and investigated between January 1, 1969 and June 30, 1970. The study team, in each case, recommended that no improvements be made. For both the 0.3-mile and 0.1-mile segments, it is obvious that the number of accidents which occurred during the one-year period immediately prior to the reference date is abnormally high. If the comparison is made between the first-year before and first-year after accident histories, as was done in the previous analysis, similar results would be obtained for these locations although no improvements

TABLE 3

BENEFIT-COST RATIOS FOR LOCATIONS WHERE IMPROVEMENTS WERE MADE (Completion Date Between January 1, 1968 and June 30, 1971)

ACCIDENT COST PROCEDURE	0.3-MILE SEGMENTS			0.1-MILE SEGMENTS		
	BENEFIT[a] ($)	COST[b] ($)	B/C	BENEFIT[a] ($)	COST[b] ($)	B/C
Total Cost of Accidents (Including Indirect Costs)	3,102,700	484,630	6.40	2,580,500	484,630	5.32
Direct Cost of Accidents	1,554,960	484,630	3.21	1,234,090	484,630	2.55

[a]Benefits defined as the savings in accident cost (computed by subtracting the year-after accident cost from the year-before accident cost).

[b]Costs defined as the sum of the cost of improvements ($178,130) and the administrative cost ($306,500 or $500 per investigation).

TABLE 4

ACCIDENT SEVERITY AND ACCIDENT-TYPE DISTRIBUTION FOR LOCATIONS WHERE IMPROVEMENTS WERE MADE (Completion Date Between January 1, 1968 and June 30, 1971)

	0.3-MILE SEGMENTS		0.1-MILE SEGMENTS	
	FIRST-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD	FIRST-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD
Severity Index[a]	2.79	2.67	2.82	2.81
Percentage of Various Types of Accidents				
PDO	66.4	66.2	65.7	65.4
A-Type	13.3	12.1	13.3	14.0
B-Type	9.0	10.2	9.2	8.6
C-Type	8.8	9.9	9.1	10.2
Fatal	2.5	1.6	2.7	1.8
Total	100.0	100.0	100.0	100.0

[a]See APPENDIX A

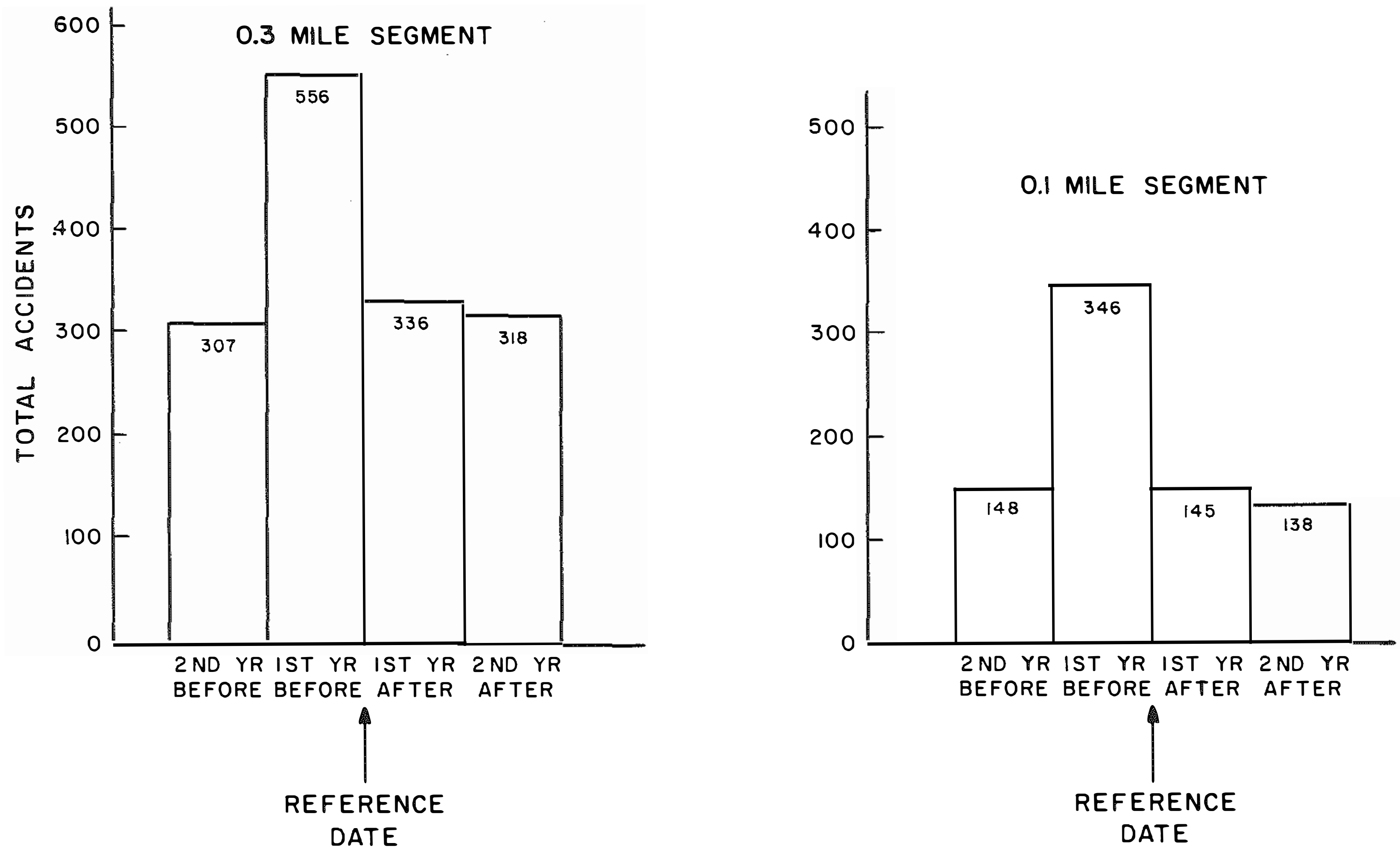


Figure 1. **Accident History for No-Improvement-Recommended Locations Having Reference Dates between January 1, 1969 and July 30, 1970 (99 Locations).**

were actually made. It is apparent that the method for selecting these locations has resulted in the selection of some locations where the high number of accidents was largely due to random or spurious variations. It is also important to note that the second-year before accident data is very similar to the first- and second-year after data and, therefore, may be considered as more representative of the long-term accident experience than the first-year before data.

Figure 2 is a similar presentation for the 109 improved locations having reference dates between January 1, 1969 and July 30, 1970. Here, too, the first-year before shows many more accidents than the other years studied. The important difference between this data set and the data of Figure 1 is that, in this case, the second-year before exceeded the first- and second-year after accidents -- indicating the value of safety improvements.

Data presented in Figures 1 and 2 clearly show that the accident data obtained during a one-year period in advance of the reference date are not completely reliable indicators of the actual long-term accident experience. A more reliable indicator of the before-improvement accident experience is the second-year before accident data.

Modified Before-and-After Evaluations

Considerations of the "peaking" effect led to the adoption of a modified procedure for evaluating the effectiveness of the spot-improvement program. In this analysis, the before period was represented by the second-year before the reference date; and, as before, the after period was represented by the first-year after the reference date. A total of 168 improved locations were thus available for evaluation, each of which had a reference date between January 1, 1969 and June 30, 1971. There were also 134 investigations during this time period which resulted in no improvements being recommended. The same procedures were used in evaluating this modified accident data set as was used in the initial evaluation.

Table 5 summarizes accident data for those locations where improvements were recommended and completed. The numbers and types of accidents are given for the second year preceding and the first year following the dates of completion of the improvements. The total number of accidents were reduced by a large percentage in the after period. The reduction in total accidents was found to be 25 percent and 31 percent for the 0.3-mile and 0.1-mile segments, respectively. This reduction in accidents was found to be statistically significant at the 0.05 level using the chi square test. Another statistical test was used to substantiate the chi square test. This test showed that the reduction was significant at a level of 0.005 (see APPENDIX B). Therefore, using the second-year before and first-year after data, the spot-improvement program has proven to be effective in reducing accidents at high-accident locations. Also, reduction in accidents was greater for the 0.1-mile segments than the 0.3-mile segments, as it was

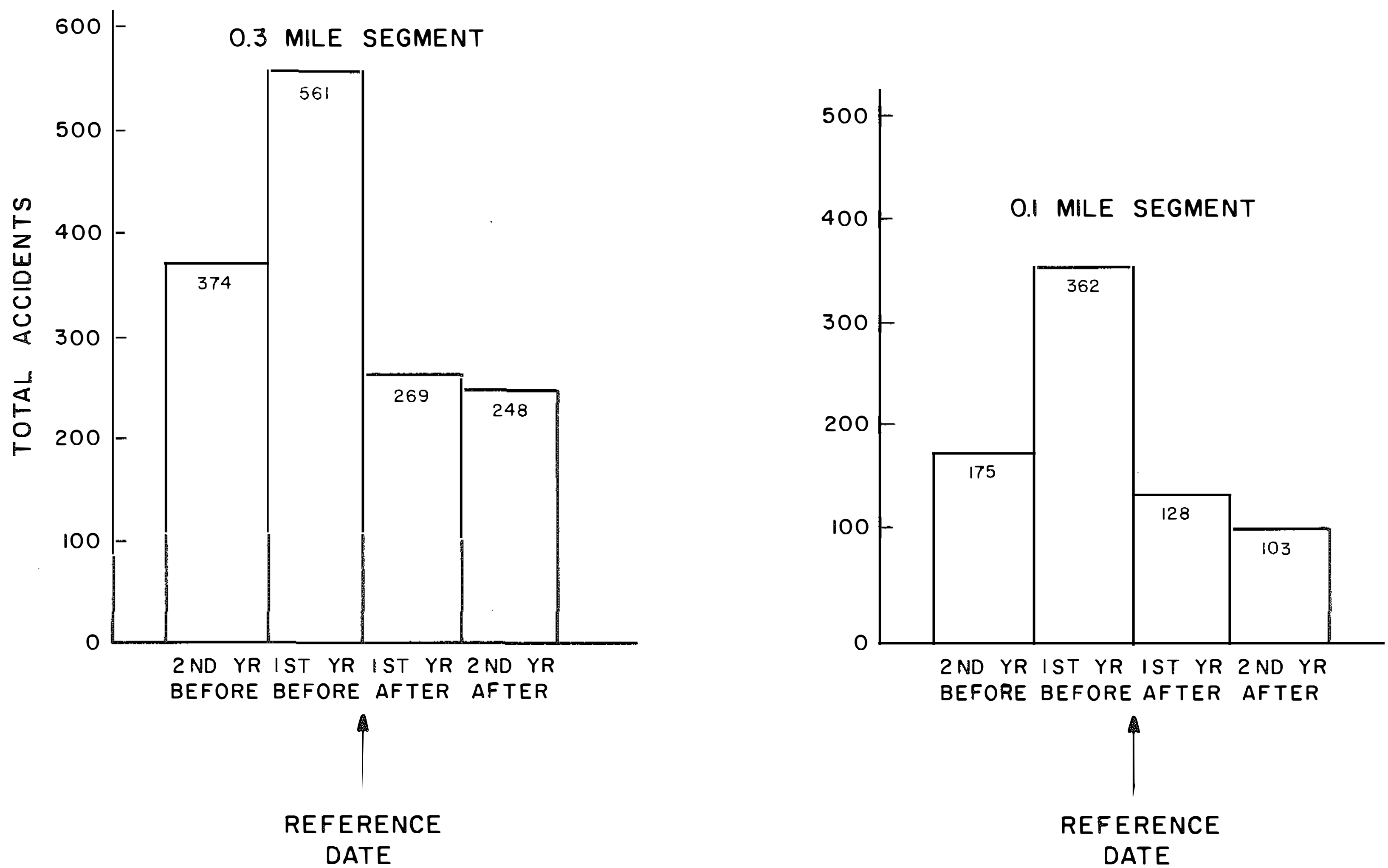


Figure 2. Accident History for Improved Locations Having Reference Dates between January 1, 1969 and July 30, 1970 (109 Locations).

TABLE 5

ACCIDENT SUMMARY FOR LOCATIONS WHERE IMPROVEMENTS WERE MADE
(Completion Date Between January 1, 1969 and June 30, 1971)

TYPE OF ACCIDENT OR INJURY	0.3-MILE SEGMENTS			0.1-MILE SEGMENTS		
	SECOND-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD	PERCENT REDUCTION	SECOND-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD	PERCENT REDUCTION
Accidents						
PDO	400	300	25.0	200	133	33.5
A-Type[a]	88	68	22.7	49	41	16.3
B-Type	77	48	37.7	35	17	51.4
C-Type	42	39	7.1	21	21	0.0
Fatal	14	10	28.6	8	5	37.5
Total	621	465	25.1	313	217	30.7
Injuries						
A-Type	149	101	32.2	104	56	46.2
B-Type	152	99	34.9	93	43	53.8
C-Type	112	85	24.1	77	40	48.1
Total	413	285	31.0	274	139	49.3
Fatalities	19	16	15.8	9	6	33.3

[a]An injury accident is classified according to the most severe injury to any person involved.

in the previous evaluation.

Benefit-cost ratios were also computed using the same procedure as before. Resulting benefit-cost ratios are shown in Table 6. Benefit-cost ratios representing both accident cost procedures were greater than 1.0 for the 0.3-mile segments. Benefit-cost ratios were less than 1.0 using direct costs at the 0.1-mile segments -- it would be greater than 1.0 if the time period were extended to 18 months. The total cost method in combination with 0.1-mile segments yielded benefit-cost ratios greater than 1.0.

Table 7 shows there were no significant changes in accident severity between the before-and-after periods, which agrees with the conclusion from the first analysis. Percentages of the various types of accidents also show there were no significant changes in the before and after accident severity.

Inventory of Safety Improvements

Table 8 gives an abbreviated summary of safety measures used; APPENDIX C provides a more detailed inventory. Table 8 shows that a majority of the improvements involved signs, and this accounts for the low average cost of $238 per safety measure. The two most expensive improvements made during the study period cost $5000; one involved installation and the other involved modification of a traffic signal. At most locations, more than one safety measure was used, which explains why there were 748 individual measures used for the 366 sites. The average cost of a safety improvement was $487.

Classification of Sites

In addition to the evaluation of the entire program, it was felt that useful information may be obtained by classifying the improved locations into a few broad classes and determining their relative effectiveness.

Four basic classes were used. They were: intersections on US and KY routes, curves on US and KY routes, tangents on US and KY routes, and interstate sections. An effort was made to divide the sites into rural and urban areas, but this proved not to be feasible because of the small number of urban area improvements. Also, the number of improvements made on interstate sections were so few that dividing the improvements into more precise types proved impractical. Tables 9 and 10 show the results obtained after summarizing accidents by type of site. Table 9 compares accident reductions while Table 10 compares severity indices. Table 11 gives the average severity index of all accidents studied (first and second year before accidents as well as first year after) by class of site.

In the comparison of first-year before and first-year after accident data (Table 9) the reduction in accidents for intersections was less than the reduction for the other types of sites. For the second-year before and the first-year after comparison, accident reduction for intersections was again below that

TABLE 6

BENEFIT-COST RATIOS FOR LOCATIONS WHERE IMPROVEMENTS WERE MADE
(Completion Date Between January 1, 1969 and June 30, 1971)

ACCIDENT COST PROCEDURE	0.3-MILE SEGMENTS			0.1-MILE SEGMENTS		
	BENEFIT[a] ($)	COST[b] ($)	B/C	BENEFIT[a] ($)	COST[b] ($)	B/C
Total Cost of Accidents (Including Indirect Costs)	520,600	228,200	2.28	526,300	228,200	2.31
Direct Cost of Accidents	270,410	228,200	1.18	152,825	228,200	0.67[c]

[a]Benefits computed by subtracting the first-year after accident cost from the second-year before accident cost.

[b]Cost of improvements was $77,200 and the administrative cost was $151,000.

[c]In 18 months, this benefit-cost ratio would be greater than one.

TABLE 7

ACCIDENT SEVERITY AND ACCIDENT-TYPE DISTRIBUTION
FOR LOCATIONS WHERE IMPROVEMENTS WERE MADE
(Completion Date Between January 1, 1969 and June 30, 1971)

	0.3-MILE SEGMENTS		0.1-MILE SEGMENTS	
	SECOND-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD	SECOND-YEAR BEFORE PERIOD	FIRST-YEAR AFTER PERIOD
Severity Index[a]	2.88	2.89	3.00	3.24
Percentage of Various Types of Accidents				
PDO	64.4	64.5	63.9	61.3
A-Type	14.2	14.6	15.7	18.9
B-Type	12.4	10.3	11.2	7.8
C-Type	6.7	8.4	6.7	9.7
Fatal	2.3	2.2	2.5	2.3
Total	100.0	100.0	100.0	100.0

[a]See APPENDIX A

TABLE 8

SUMMARY OF SAFETY MEASURES USED

TYPE OF IMPROVEMENT	NUMBER
Installation	505
Refurbishing	85
Relocation	46
Upgrading	85
Removing	27
Total	748

SAFETY MEASURE	TIMES USED
Warning Signs	323
Regulatory Signs	91
Guidance Signs	22
Traffic Signal	10
Beacon	21
School Signal	1
Signal Adjustments	2
Roadway Markings	97
Post Delineators	43
Channelization	16
Construction	28
Shoulder Maintenance	26
General Maintenance	66
Lighting	2

TABLE 9

COMPARISON OF ACCIDENT REDUCTION BY CLASS OF SITE

LOCATION CATEGORY	NUMBER OF LOCATIONS	PERCENT REDUCTION IN ACCIDENTS	
		0.3-MILE SEGMENTS	0.1-MILE SEGMENTS
Comparing First-Year Before to First-Year After			
Intersections	203	36	52
Curves	88	52	68
Tangents	42	53	68
Interstates	16	56	64
Comparing Second-Year Before to First-Year After			
Intersections	99	18	28
Curves	40	42	53
Tangents	17	47	40
Interstates	12	35	18

TABLE 10

COMPARISON OF SEVERITY INDICES
BY CLASS OF SITE

LOCATION CATEGORY	NUMBER OF LOCATIONS	SEVERITY INDEX 0.3-MILE SEGMENTS BEFORE	SEVERITY INDEX 0.3-MILE SEGMENTS AFTER	SEVERITY INDEX 0.1-MILE SEGMENTS BEFORE	SEVERITY INDEX 0.1-MILE SEGMENTS AFTER
Comparing First-Year Before to First-Year After					
Intersections	203	2.60	2.55	2.68	2.78
Curves	88	3.22	3.08	3.32	2.97
Tangents	42	2.64	2.53	2.40	2.20
Interstates	16	3.03	2.68	3.29	3.31
Comparing Second-Year Before to First-Year After					
Intersections	99	2.65	2.82	2.71	3.24
Curves	40	3.33	3.10	3.22	3.48
Tangents	17	2.13	3.17	2.36	1.90
Interstates	12	3.07	2.38	3.07	2.76

TABLE 11

SEVERITY INDEX OF ALL ACCIDENTS STUDIED
BY CLASS OF SITE

LOCATION CATEGORY	SEVERITY INDEX
Intersections	2.59
Curves	3.20
Tangents	2.54
Interstates	2.96

for curves and tangents. Interstate sites showed a small accident reduction, but the small sample size could give inconclusive results. Apparently, improvements at intersections resulted in a smaller reduction in accidents than the other types of sites although the improvement was still significant. In most cases, accident reduction for the other sites were very similar. This could be due to the fact that intersections present a more complicated accident situation than other types of locations because of the many variables present. Thus, it is more difficult to bring about a large reduction in accidents by making one improvement.

In the comparison of before and after data in Table 10, no significant pattern was discernable. The before SI was greater than the after SI in some cases and smaller in other cases.

From Table 11, it can be seen that accidents at curves were the most severe. This seems reasonable since such accidents would largely consist of vehicles running off the road, a severe type of accident. Accidents on interstates were second in severity, probably resulting from high-speed accidents. Accidents at intersections and tangents had similar severity indices, which were below those of the other two classes.

Case Histories

APPENDIX E gives the "before" and "after" accident experience at a few of the improved locations across the state. These examples relate in detail how the improvements have actually effected accident reduction.

Data Storage and Retrieval

After becoming aware of data needed to complete this study, it became apparent that a more efficient method of storing necessary information would be advisable. There will probably be future studies to evaluate the program as it progresses, and new data storage techniques would be helpful. A form similar to the one presented in Figure 3 would resolve many problems encountered. This data sheet would contain accident data necessary to conduct a study of this type. In this study, it was necessary to prepare time-consuming summaries from computer printouts containing all state-reported accidents. This form would require only a small storage area; and, in addition to accident data, it would supply necessary information concerning the location and completion date, cost, and types of improvements made as well as traffic volumes. This form would require updating to include accidents which occur in the two years following the improvement.

Another source of information which would be helpful for more detailed studies would be "before" and "after" photographs of the locations. Photographs would show what traffic control devices were present before and after the improvement and thus would enable studies dealing with accident reductions for the various types of safety measures. This is not possible with data now available because the extent

LOCATION:

COUNTY ________

ROUTE ________

MP ________

DESCRIPTION ____________________

		TYPE OF ACCIDENT					TOTAL INJURIES				TOTAL ACC.	ADT
		PDO	A	B	C	K	A	B	C	K		
BEFORE	FIRST YEAR											
	SECOND YEAR											
AFTER	FIRST YEAR											
	SECOND YEAR											

IMPROVEMENT	COMP. DATE	COST

Figure 3. Spot-Improvement Program Data Sheet.

of prior traffic control devices is not known. Collision diagrams are always drawn when a location is investigated; the inclusion of these diagrams in the data file would be beneficial. A condition diagram would also be useful and should be included in the file. As can be seen, a small file can be maintained for each location which would enable further and more detailed studies of the spot-improvement program.

CONCLUSIONS

The objective of this study was to determine the effectiveness of the safety improvement program in reducing accidents at high-accident locations. The following are the major conclusions which were drawn from the analyses:

1. The spot-improvement program has resulted in a significant reduction in accidents at high-accident sites.
2. The cost of this program has been a good investment as denoted by favorable benefit-cost ratios.
3. Severity of the accidents did not change significantly as a result of the spot-improvement program.
4. In this type of study, second-year before accident data was found to be more representative of the long-term accident experience than the first-year before data.
5. A more efficient method of data storage would enable future studies and evaluations of the program to be made more expeditiously.

APPENDIX A

CALCULATION OF DIRECT COSTS AND THE SEVERITY INDEX FORMULA

CALCULATION OF DIRECT COSTS AND THE SEVERITY INDEX FORMULA

CALCULATION OF DIRECT COSTS

Direct costs resulting from motor-vehicle accidents include property damage, medical costs, loss of use of vehicle, value of work time lost, legal costs, and other items. Excluded costs are called "indirect costs" and consist mainly of losses of future earnings. Direct costs were derived from a study by the Illinois Division of Highways *(8)*. In that study, direct costs per involvement were calculated for various categories of accidents. The following table was taken from the Illinois study:

COST PER INVOLVEMENT
ILLINOIS, 1958

	FATAL ACCIDENTS	NON-FATAL INJURY ACCIDENTS	PROPERTY DAMAGE ONLY ACCIDENTS
Rural	$ 5,527	$ 1,421	$ 272
Urban	$ 4,215	$ 910	$ 144
All	$ 5,085	$ 1,015	$ 159

The cost per accident can be found by multiplying the cost per involvement by the corresponding involvement rate. The involvement rate is the ratio of the number of vehicles involved to the number of accidents. The following table gives the breakdown of the total number of state police-reported accidents in Kentucky for 1971 *(9)*:

NUMBER OF ACCIDENTS
KENTUCKY, 1971

	FATAL ACCIDENTS	NON-FATAL INJURY ACCIDENTS	PDO ACCIDENTS	TOTAL ACCIDENTS
Rural	737	8,137	13,971	22,845
Urban	145	107	290	542
All	882	8,244	14,261	23,387

As can be seen, nearly all state police-reported accidents were in rural areas. Using the percentages of accidents which occurred in rural and urban areas, the cost per involvement figures can be adjusted to give one cost for each severity class in Kentucky:

ADJUSTED COST PER INVOLVEMENT

FATAL ACCIDENTS	NON-FATAL INJURY ACCIDENTS	PDO ACCIDENTS
$5,395	$1,414	$269

Since the total number of accidents in each severity class is known, and the total number of vehicles involved in each severity class can also be found, the involvement rates can be determined from a ratio of these two values and are shown in the following table:

KENTUCKY, 1971

	FATAL ACCIDENTS	NON-FATAL INJURY ACCIDENTS	PDO ACCIDENTS
Number of Vehicles Involved	1,288	13,142	24,847
Number of Accidents	882	8,244	14,261
Involvement Rates	1.46	1.59	1.74

Illinois' figures for cost per involvement and Kentucky's involvement rates produce the table below:

DIRECT COST PER ACCIDENT
KENTUCKY, 1971

FATAL ACCIDENTS	NON-FATAL INJURY ACCIDENTS	PDO ACCIDENTS
$7,877	$2,248	$468

Since these cost figures are based on 1958 Illinois cost figures, adjustments must be made to convert the 1958 price levels to 1971 price levels and Illinois price levels to Kentucky price levels. The consumer price index (CPI) was used to adjust for the rise in the general price level since 1958 *(10)*. The ratio of the CPI of 1971 to the CPI of 1958 was found to be 1.401. Adjustment of Illinois to Kentucky price levels was based on American Chamber of Commerce figures for various cities in the United States *(11)*. The following 1971 indices were given for five cities in Illinois and Kentucky, and the scale on which they are based has an overall average set to 100:

ILLINOIS CITIES	KENTUCKY CITIES
110.0	88.8
98.0	90.5
92.2	97.8
113.2	94.8
102.5	89.7
AVERAGE 103.18	92.32

92.32/103.18 = 0.895

The Kentucky average was about 10 percent lower than the Illinois figure.

A factor of 1.401 times 0.895 must be used to adjust the 1958 Illinois cost data to comparable 1971 Kentucky cost data. The factor was 1.254 and resulted in the following:

DIRECT COST PER ACCIDENT
KENTUCKY, 1971

FATAL ACCIDENTS	NON-FATAL INJURY ACCIDENTS	PDO ACCIDENTS
$9,880	$2,820	$585

These are the costs for the general injury accident only. Considering the number of Type A, B, and C injuries and comparing their relative severities, costs for each of the other categories were obtained.

The following number of fatalities and various types of injuries occurred in Kentucky in 1971 *(9)*:

A-type injury	-	4,438
B-type injury	-	5,191
C-type injury	-	5,256
Fatalities	-	1,023

By definition, A-type injuries are more severe than B-type injuries, and B-type injuries are more severe than C-type injuries. Therefore, it is logical to conclude that A injuries will cost more than B injuries, and B injuries in turn will cost more than C injuries. For a given number of non-fatal injury accidents, the total accident cost is known from the previous table. If a ratio of the costs for each non-fatal injury accident type is assumed, a cost for each injury-type accident can be obtained. Ratios used in a study in North Carolina *(12)* were 1.732, 1.732, and 3.0 for A to B, B to C, and A to C injury groups. These ratios appeared to be reasonable and were used in this study. Using these ratios and the number of injuries of each type[a], the following costs were obtained:

Injury-Type Accident	Cost
A	\$4,570
B	\$2,635
C	\$1,525

DEVELOPMENT OF SEVERITY INDEX FORMULA

The severity index (SI) formula attempts to place a value on the average severity of the accidents occurring at a location. The number of accidents before and after an improvement give a good indication of the effectiveness of the improvement, but it does not show how the improvement has affected accident severity. The severity index is determined by dividing the number of equivalent property-damage-only (EPDO) accidents by the total number of accidents. Factors, based on direct cost by severity class, are applied to injury and fatal accidents to determine the number of EPDO accidents. Accident severity increases as the severity index increases. Using the cost of each type of accident or injury and the number of accidents or injuries, the weighting factors for the various injury types were obtained. It should be noted that fatal accidents and A-injury accidents were grouped together; although fatals are much more costly, they are also much rarer in occurrence. Accidents classified as B injury or C injury were also grouped together. The calculations are as follows:

Fatal (K-type) and A-injury Accidents

$$[4438 (\$4570) + 1023 (\$9880)]/(4438 + 1023) = \$5564$$

$$\$5564/\$585 = 9.5$$

B-injury and C-injury Accidents

$$[5256 (\$1525) + 5191 (\$2635)]/(5256 + 5191)] = \$2077$$

$$\$2077/\$585 = 3.5$$

The resulting formula is

$$EPDO = 9.5 (K + A) + 3.5 (B + C) + PDO$$

An injury accident is classified according to the most severe injury to any person involved. The severity index (SI) is found by dividing the number of EPDO accidents by the total number of accidents, N_t. It indicates the average severity of the accidents and is expressed as

$$SI = EPDO/N_t.$$

[a]The total number of injuries of each type were used because a summary of accidents by type of accident was not available. The distribution of the type of injuries should approximate the distribution of injury-type accidents.

APPENDIX B

STATISTICAL TESTS

STATISTICAL TESTS

In this study, two statistical tests were used. The first test was the chi square test to determine whether the number of accidents occurring after corrective measures were instituted was reliably less than the number before. The curve in Figure B-1 shows the percent accident reduction required to be significant at the 0.05 level for a given number of before accidents *(13)*. For the number of before accidents considered in this study, a 19 percent reduction in accidents was necessary to prove that observed reductions were due to anything more than chance alone. This was true for both analyses used. Data collected showed an accident reduction greater than 19 percent in all cases studied, indicating a significant reduction in accidents had occurred.

It must be noted that the chi square test requires fulfillment of certain statistical assumptions to be wholly valid. There is no way to prove these assumptions are met in any given field situation. Furthermore, there is never good control over all variables influencing changes in accident incidence. The curve shown can be used as an estimate of the percentage reduction in accidents required to achieve statistical significance, but where improvement measures show a significant influence on accident incidence, a more intensive evaluation of them should be undertaken. For this reason, a second statistical test was performed to further evaluate the improvements.

The second statistical test asked the question, "Does the average of B exceed the average of A?", where B and A represent the number of before and after accidents, respectively *(14)*. The case where observations are paired was used because for each location, before and after accidents were obtained, and these before and after accidents are used as the pairs. In this test, the average difference ($\bar{x}_d$) and the standard deviation of the difference of the before and after periods were obtained. For a certain level of significance, whether the average of B exceeds the average of A can be determined. The second-year before and first-year after data were considered because this was the most conservative comparison. Therefore, if this comparison was found to be significant, other comparisons would be also. The following is the result of this test considering both the 0.3-mile segments and the 0.1-mile segments:

0.3-Mile Segments

$\bar{x}_d = (\overline{x_B - x_A}) = 0.99$

n = number of cases = 168

d.f. = degrees of freedom = 167

s_d = standard deviation = 2.71

For significance level = .01

$t_{.99}$ for 167 d.f. = 2.326

$u = t_{gg}\ s_d/\sqrt{n} = 2.326(2.71/12.96) = 0.49$

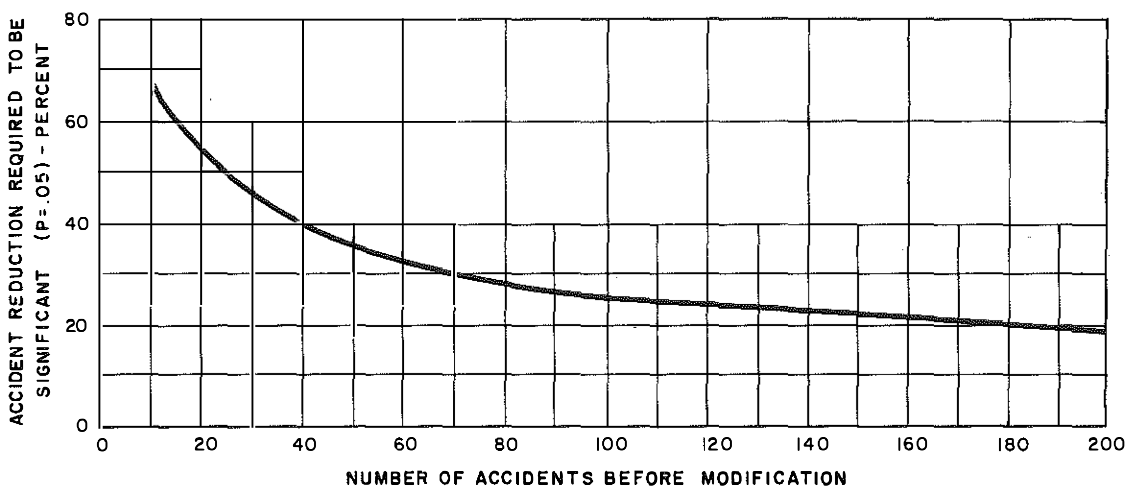


Figure B-1. Chi Square Curves for Determining the Statistical Significance of Accident-Reducing Techniques.

If $\bar{x}_d > u$, decide that the average of B exceeds that of A; otherwise, there is no reason to believe the average of B exceeds that of A.

$x_d = 0.99$, which is larger than $u = 0.49$. Conclude that average for B (number of "before" accidents) exceeds the average for A (number of "after" accidents).

For significance level = 0.05

$t_{.995}$ for 167 d.f. = 2.576

$u = 2.576\ (2.71/12.96) = .54$

$\bar{x}_d = 0.99$, which is larger than u. Conclude that average for B exceeds the average for A.

0.1-Mile Segments

$\bar{x}_d = .57$

$n = 168$

d.f. = 167

$s_d = 1.88$

For significance level = .01

$u = 2.326\ (1.88/12.96) = 0.34$

$\bar{x}_d = 0.57$, which is larger than u. Conclude that average for B exceeds the average for A.

For significance level = .005

$u = 2.576\ (1.88/12.96) = 0.37$

$\bar{x}_d = 0.57$, which is larger than u. Conclude that average for B exceeds the average for A.

This statistical test was also used to test the significance of the small decrease in severity index between the "before" and "after" periods. Severity indices of the first-year before and first-year after periods (0.3-mile segments) were compared since they showed the largest decrease:

$\bar{x}_d = .07$

$n = 307$

d.f. = 306

$s_d = 2.48$

For significance level = .05

$t_{.95}$ for 287 d.f. = 1.660

$u = t_{.95}\ s_d/\sqrt{n} = 1.660 \times (2.48/17.52) = .23$

$\bar{x}_d = 0.07$, which is smaller than u. Conclude that there is no reason to believe the average of B exceeds that of A and, therefore, the severity of the "before" accidents is not greater than the severity of the "after" accidents.

APPENDIX C

INVENTORY OF SAFETY MEASURES

INVENTORY OF SAFETY MEASURES

SAFETY MEASURE	TYPE OF IMPROVEMENT					
	INSTALLATION	REFURBISHING	RELOCATION	UPGRADING	REMOVAL	TOTAL
WARNING SIGNS						
ADV-	1			3		4
ADV-15	1					1
ADV-20	4					4
ADV-25	4	1	1			6
ADV-30	4					4
ADV-35	7					7
ADV-40	5					5
ADV-45	13		1	1		15
ADV-50	4					4
ADV-60	1					1
ARROW	35	1	2	10		48
CONGEST AREA	4		1	1		6
CROSSING	2		1			3
CURVE	28	1	5	18	1	53
HAZARD MARKER	2					2
ICE ON BRIDGE	3					3
MERGE	1					1
NARROW BRIDGE	2		1	1	1	5
ONE LANE BRIDGE	1					1
PREP SUDDEN STOP	31		1	4		36
PVT WIDTH TRANS	1					1
RR	1					1
ROAD NARROWS	1					1
SCHOOL	1					1
SIDE ROAD	55	1	2	12		70
SIGNAL AHEAD	1		1			2
SLIPPERY WHEN WET	11					11
STOP AHEAD	17		1	5		23
TOLL BOOTH	1					1
TRAFFIC ISLS AH	2					2
YIELD AHEAD	1					1
TOTAL						323
REGULATORY SIGNS						
BUS PARKING	1					1
KEEP RIGHT	4					4
KEEP RIGHT EX PASS	3					3
LANE USE	2					2
NO PARK	10					10
NO PASS ZONE	13	1	2	2	1	19
NO TURN	1					1
SPEED LIMIT	12		1	1		14
STOP	15	4	5	7		31
STOP HERE	1					1
YIELD	5					5
TOTAL						91
GUIDANCE SIGNS						
CHURCH			1			1
COMMUNITY COLLEGE	1					1
DESTINATION	1		2		1	4
ENTRANCE	1					1
FACTORY ENT					1	1
HOSPITAL	1					1
PARK	2					2
ROUTE MARKER	2		5	2		9
THEATER	1					1
TRUCK ENT	1					1
TOTAL						22
TRAFFIC SIGNALS						
FULL-ACT	1			1		2
PRE-TIMED	1					1
SEMI-ACT	7					7
TOTAL						10
BEACONS						
ADVANCE	8	3		1		12
INTERSECTION	6	1		2		9
TOTAL						21

SCHOOL ZONE SIGNAL	1					1
TIMING OF SIGNALS				2		2
ROADWAY MARKINGS						
ARROW	1					1
BARRIERLINE	8	1		4		13
BRIDGE ENDS		1				1
BUS PARKING	1					1
CENTERLINE	10	3	2	1		16
CURB	1					1
EDGELINE	14	1				15
GORE		2				2
GUARDRAIL	2	2				4
LANE LINE	3					3
LANE USE	2					2
NO PARK	2					2
STOP	1					1
STOP BAR	21	6	7	1		35
TOTAL						97
POST DELINEATORS						
BOARD	3					3
PANEL	2					2
RIGID	38					38
TOTAL						43
CHANNELIZATION						
BARRIER	1				1	2
MOUNTABLE	1					1
PAINTED	8	5				13
TOTAL						16
CONSTRUCTION						
CULVERT		1	1			2
DAYLIGHT	1				1	2
GUARDRAIL	1	3	1		1	6
HORIZ ALIGN			1			1
MEDIAN CROSSOVER					1	1
RELOCATE			1			1
RUMBLE STRIPS	9					9
STOR LANE	4					4
SUPER	1			1		2
TOTAL						28
SHOULDER MAINTENANCE						
LOWER		2				2
PATCH	1	6				7
RAISE	4	5				9
STABILIZE	2	3		1		6
WIDEN	1	1				2
TOTAL						26
GENERAL MAINTENANCE						
BILLBOARD					1	1
CLEAN PAVMT					2	2
DE-SLICK	6	7		2		15
DRAINAGE	2			1		3
RESURFACE	5	20		1		26
PATCH		3				3
PAVE ENTRANCE	1					1
VEGETATION					15	15
TOTAL						66
LIGHTING						
FULL	1					1
SPECIAL	1					1
TOTAL						2
GRAND TOTALS	505	85	46	85	27	748

APPENDIX D

CASE HISTORIES

CASE HISTORIES

This appendix contains a few example locations where improvements were made and which resulted in a reduction in accidents. These locations were selected to illustrate the types of improvements achieved by the spot-improvement program. For each location, a collision diagram *(15)* was drawn to show the year-before and year-after accidents. By referring to the actual accident reports, it was determined that the year-before accidents at these locations were not due to random events; thus, they could be used in the evaluation. Benefit-cost ratios were calculated using direct accident costs -- so that conservative results would be obtained. A photograph of each location is also provided.

Following is the legend used for the collision diagrams:

Patn of moving motor vehicle

Pedestrian or animal path

Fatal injury

Non-fatal injury

Rear-end collision

Collision with parked vehicle

Collision with fixed object

Overturned

Out of control

Sideswipe

Time: A = a.m. P = p.m.

Pavement: D = Dry I = icy W = wet

Weather: C = clear CL = cloudy R = rain
F = fog S = snow

Before Accidents: Black

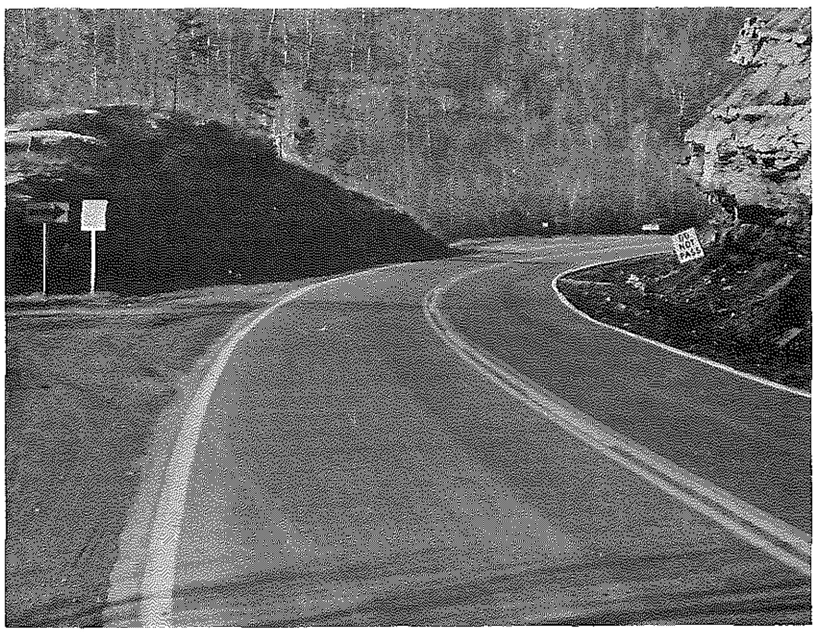
After Accidents: Red

LAUREL COUNTY, US 25 AT MP 24.5

During the year before improvement, 15 accidents occurred while there were no accidents the year after the improvement. Improvements consisted of resurfacing and installation of a warning arrow. The location is a curved section of road. All 15 of the before accidents occurred during wet weather. Three of the accidents occurred during congestion created by accidents ahead.

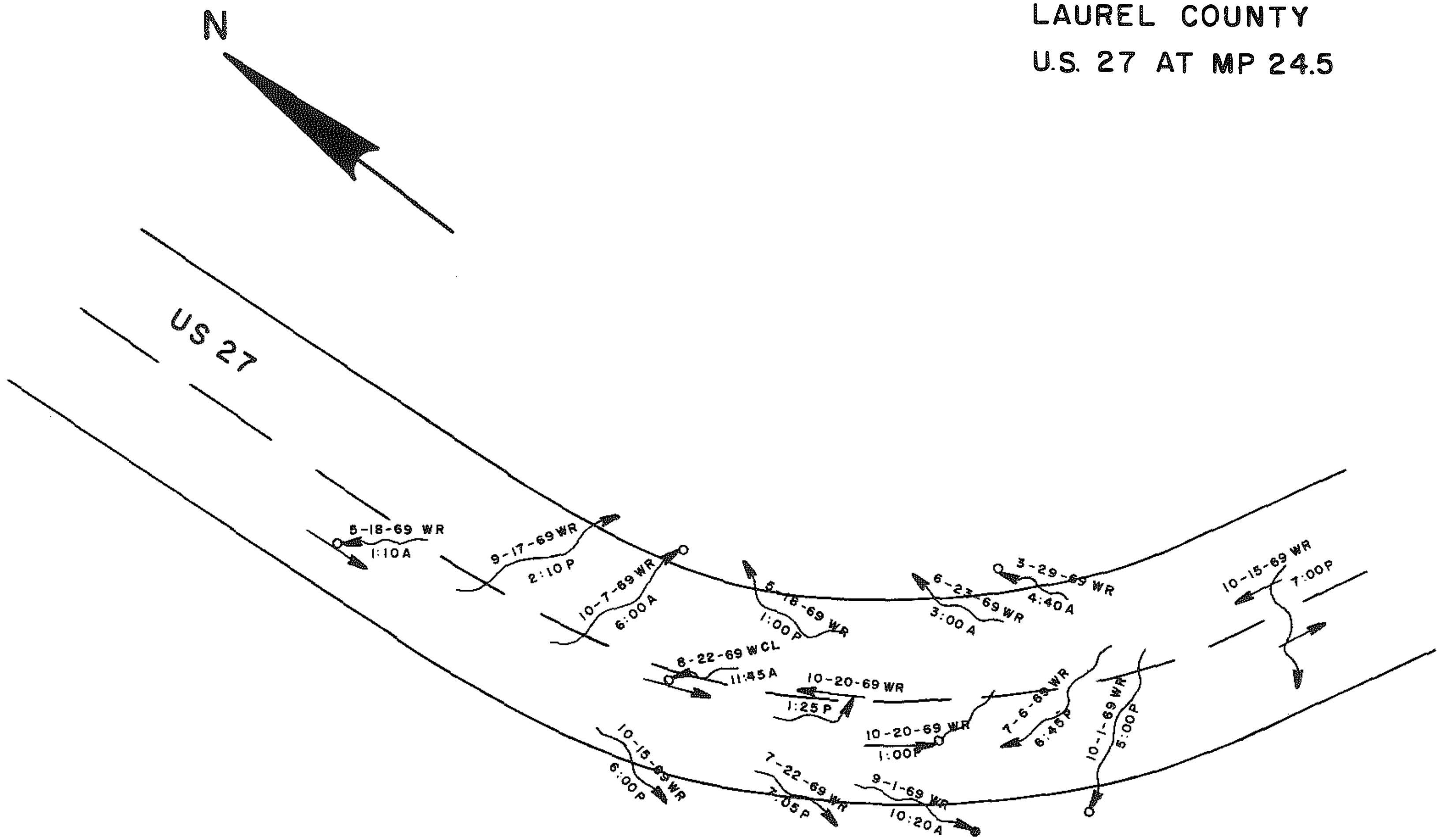
The problem here, obviously, was slippery pavement; and resurfacing increased the skid resistance of the roadway. The warning arrow also helped by warning the driver to reduce speed in the curve.

Cost of the improvement was $1,400 and there was a savings in accident costs of $32,430 when the year-before and year-after accident experience was considered. The benefit-cost ratio was 23.2.



LAUREL COUNTY

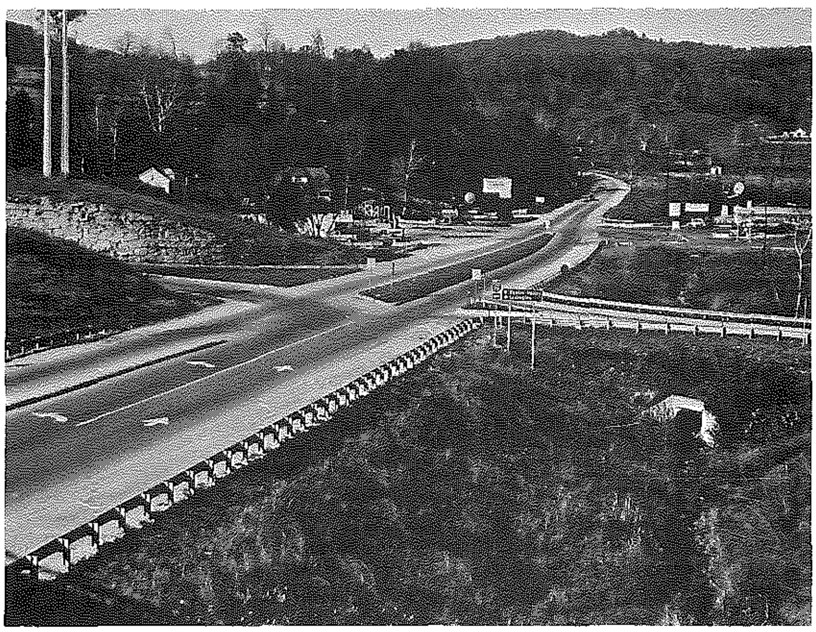
U.S. 27 AT MP 24.5



ROCKCASTLE COUNTY, US 25 AT MP 15.8

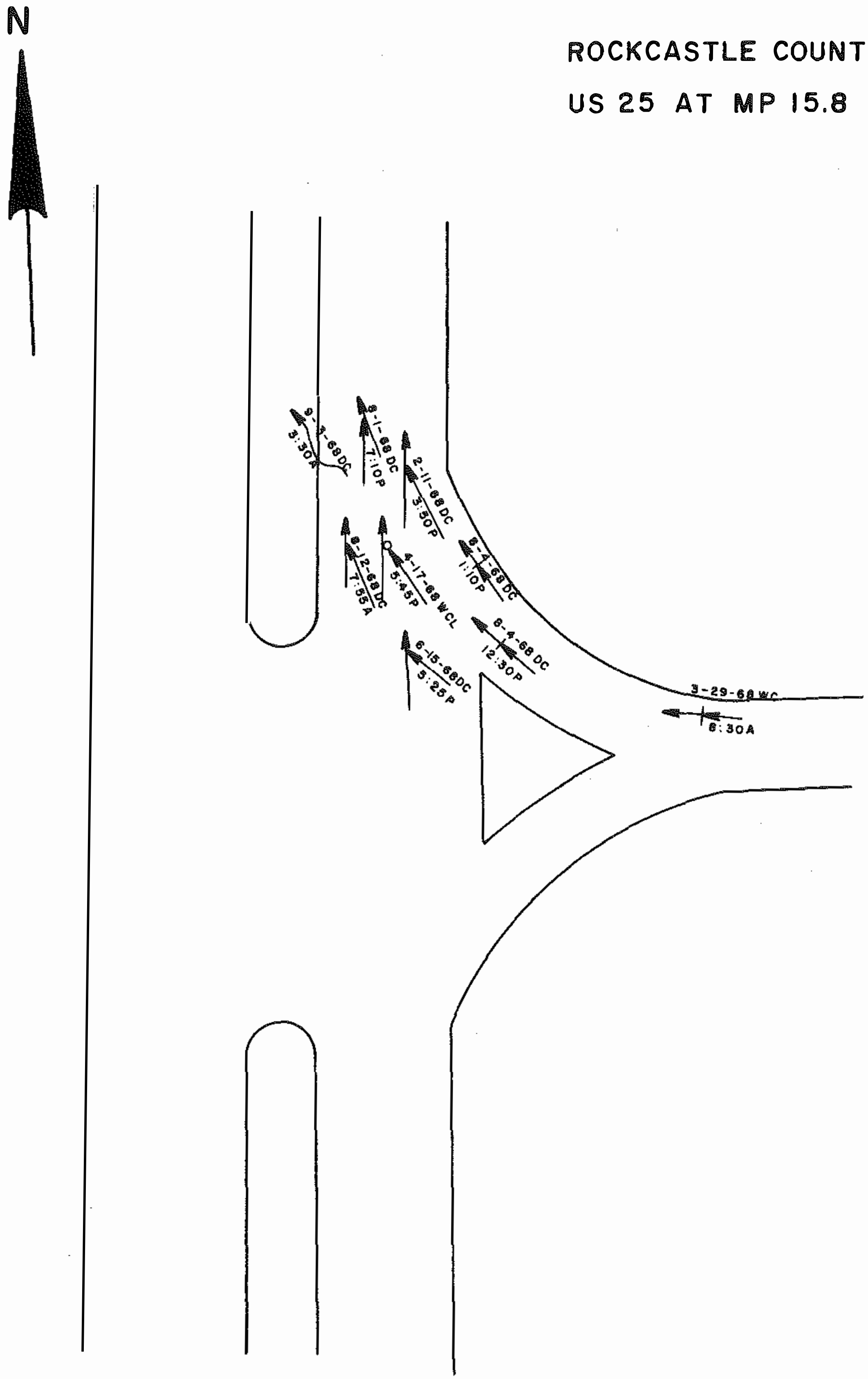
The location is an intersection of an interstate "off" ramp with US 25. The improvement involved replacing a "YIELD" sign with a "STOP" sign. There were nine accidents in the before period, none in the after period. Seven of the nine accidents were of the type which would be directly affected by the improvement. The remaining two were caused by wet pavement and a brake failure, respectively. Five of the before accidents involved failure to yield right of way when entering US 25; that is, not stopping on the ramp at the "YIELD" sign. While the "YIELD" sign does not require a driver to stop, a more restrictive sign, the "STOP" sign, was necessary to require vehicles entering US 25 from the "off" ramp to stop and yield the right of way. Two of the rear-end accidents were of the type common at "YIELD" signs -- the driver was looking to see if the road was clear and failed to see a vehicle stopped in front of him.

Cost of the improvement was $50. The direct accident savings was calculated to be $7,315, and yielded a benefit-cost ratio of 146.3.



ROCKCASTLE COUNTY

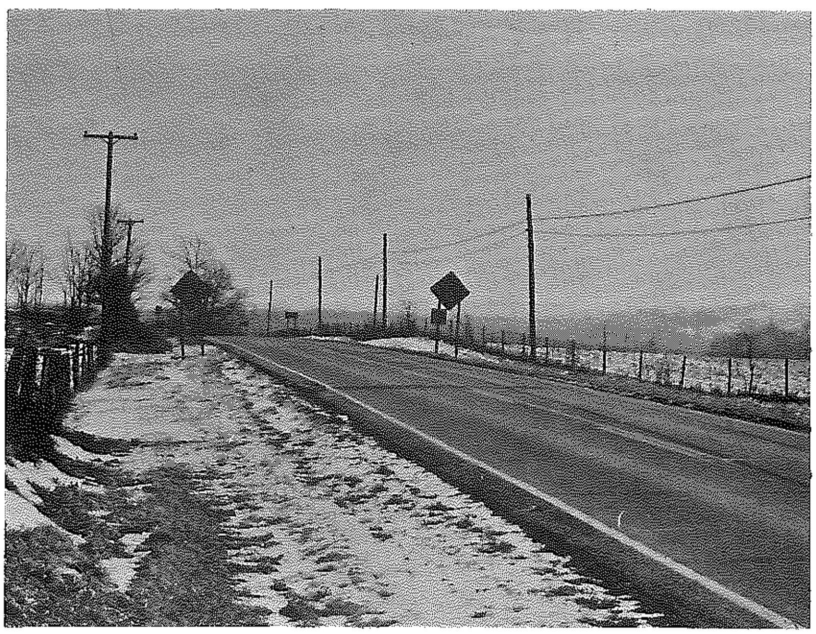
US 25 AT MP 15.8



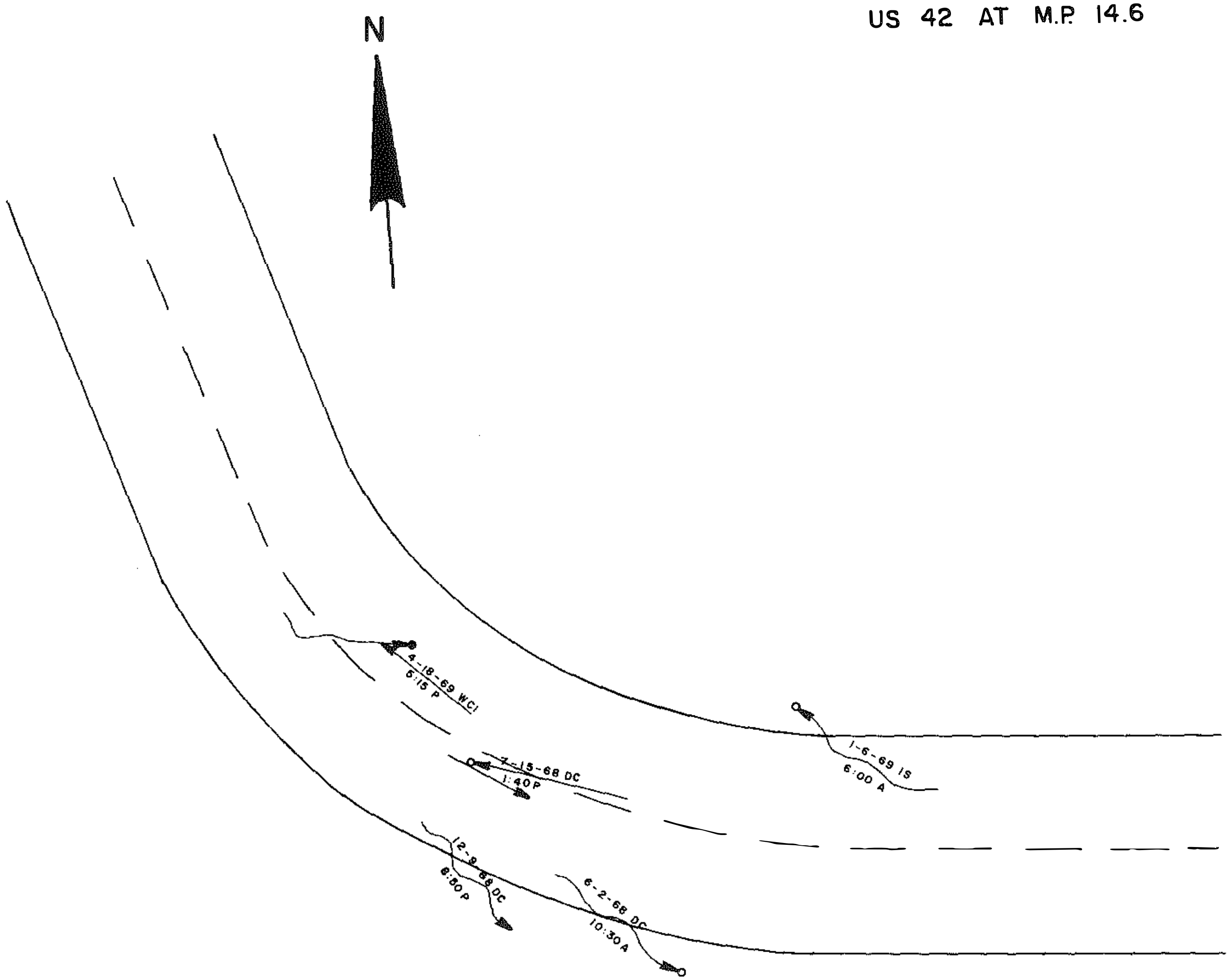
OLDHAM COUNTY, US 42 AT MP 14.6

The location is on a horizontal curve. Improvements involved installation and relocation of warning arrows for the curve as well as rigid post delineators. There were five accidents during the year prior to the improvement and no accidents during the one-year period after the improvement. In all accidents, the driver at fault was proceeding too fast to negotiate the curve. The purpose of the arrows and delineators was to warn the driver to reduce speed. Three of the accidents were single-vehicle accidents in which the driver lost control of his vehicle. One accident resulted when a car crossed the centerline and struck an oncoming vehicle. A fatal accident occurred when a driver lost control of the car and struck an oncoming vehicle. Three accidents occurred on dry pavement so slipperiness was not a major cause. Absence of accidents during the after period indicates the warning arrows and delineators are performing their function well.

The improvement cost was $300, and the accident savings was $16,320. This gives a benefit-cost ratio of 54.4.



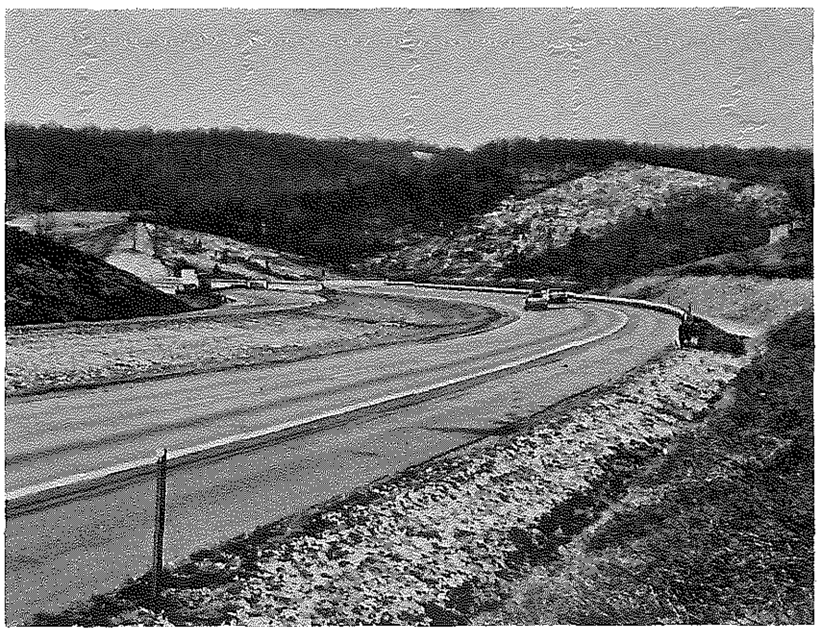
OLDHAM COUNTY
US 42 AT M.P. 14.6

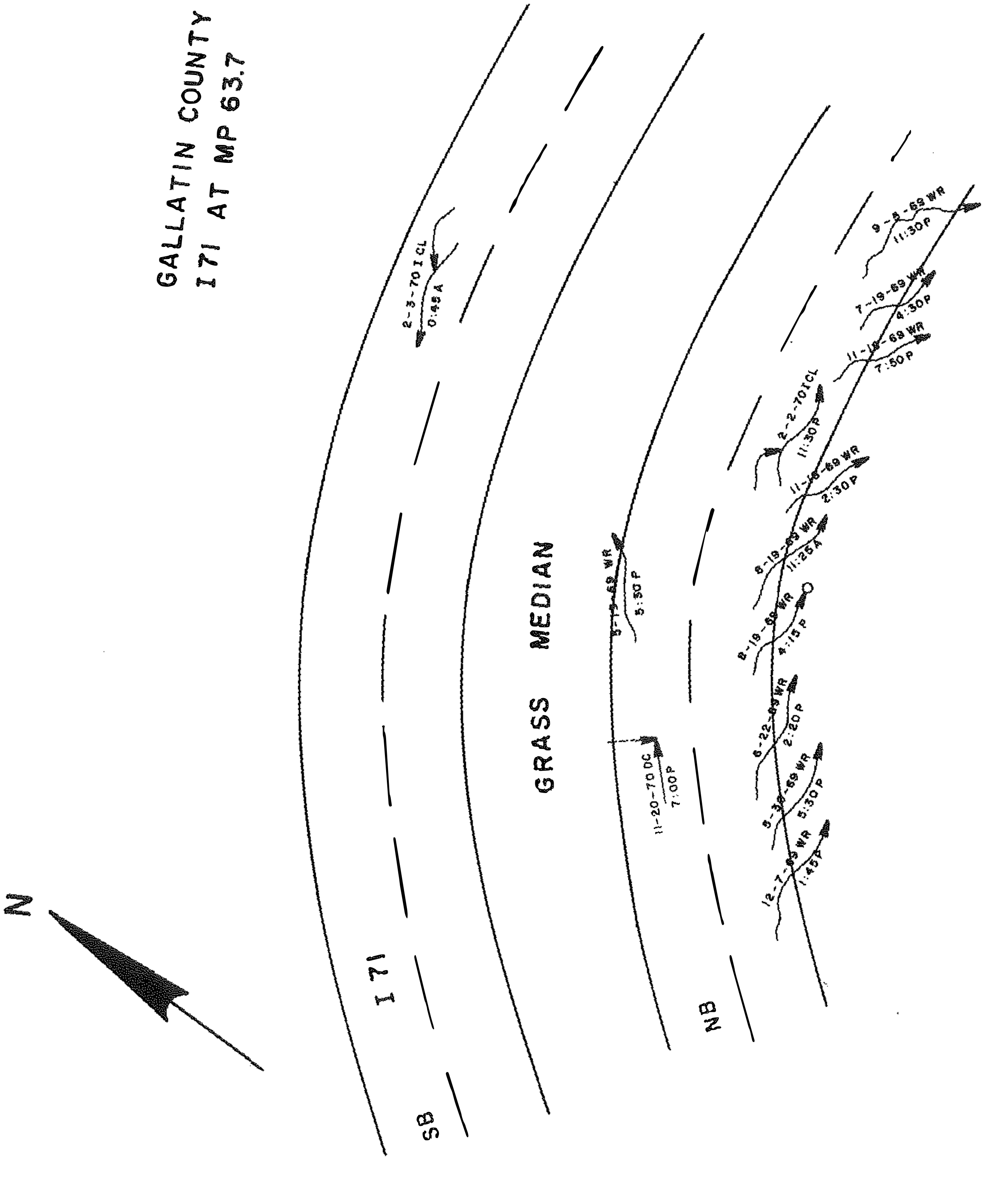


GALLATIN COUNTY, I 71 AT MP 63.7

The location is on a horizontal curve. The 12 accidents during the before period were all on wet pavement, so slippery pavement was the apparent cause of the accidents. The solution involved eliminating cross-pavement drainage and a deslicking treatment (resurfacing). Only one accident was recorded during the one-year period since resurfacing. This accident occurred during dry-pavement conditions and involved a car striking a deer.

The improvement cost was $3,000. Comparing the before and after accidents gives a direct accident savings of $10,010 and results in a benefit-cost ratio of 3.14.



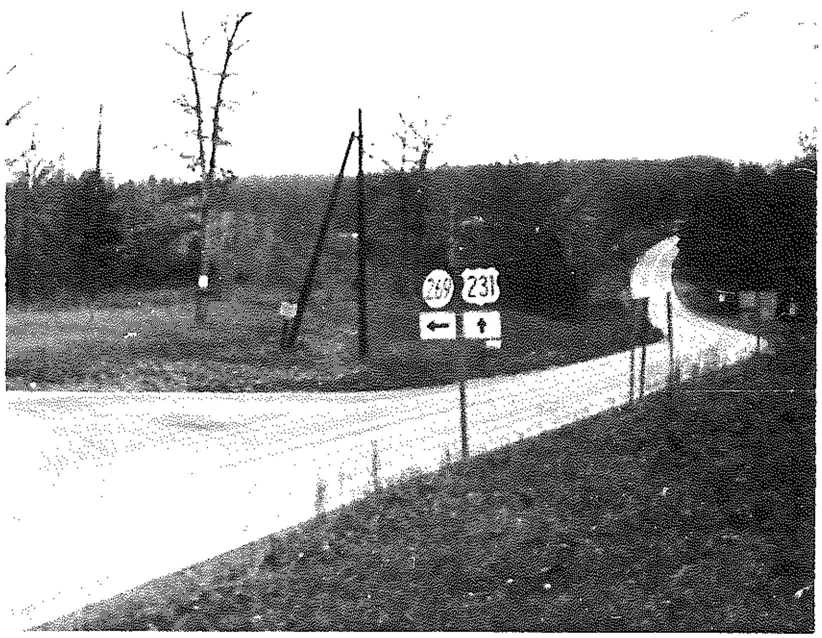


GALLATIN COUNTY
I 71 AT MP 63.7
N
I 71
SB
NB
GRASS MEDIAN
2-3-70 I CL
0:45A
5-13-69 WR
5:30P
11-20-70 DC
7:00P
9-5-69 WR
11:30P
7-19-69 WR
4:30P
11-19-69 WR
7:50P
2-2-70 I CL
11:30P
2:30P
8-19-69 WR
11:25A
2-19-69 WR
4:15P
6-22-69 WR
2:20P
5-30-69 WR
5:30P
12-7-69 WR
1:45P

OHIO COUNTY, US 231 AT MP 5.6

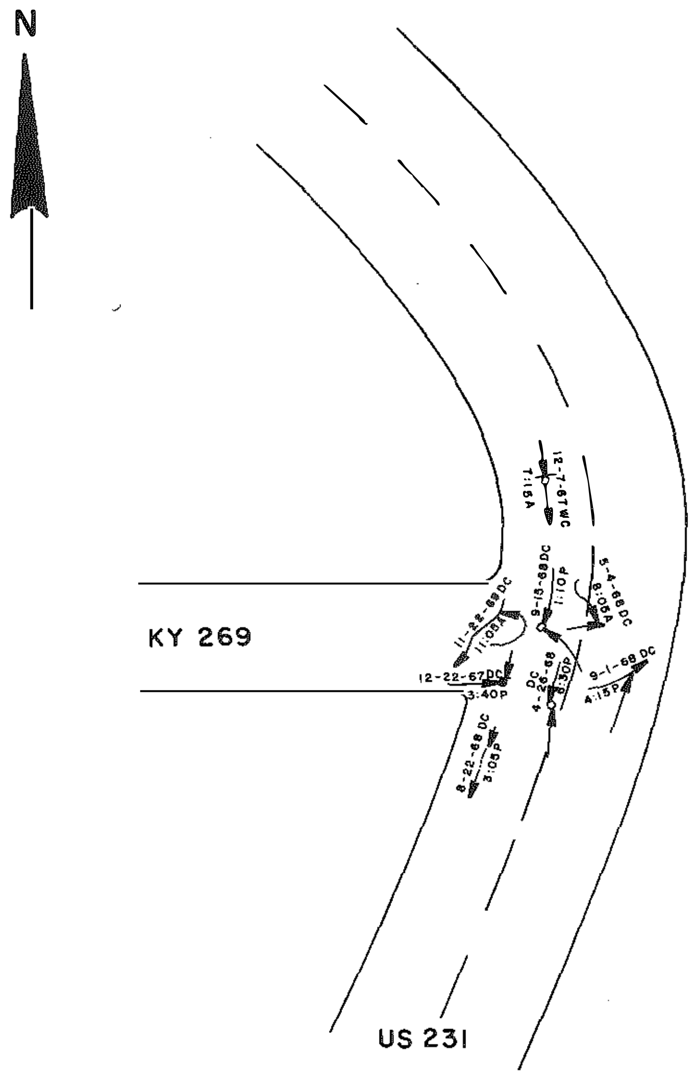
This location is the intersection of US 231 and KY 269. As was noted on some of the state police accident reports (before improvement), this was a hazardous intersection due to the curvature, road banks, and bushes along the highway. Improvement here consisted of providing better sight distance, installation of "PREPARE FOR SUDDEN STOP" signs, and painting a stop bar for traffic on KY 269. There were seven accidents in the before period and only one during the after period. This latter accident resulted from a driver losing control of the vehicle while avoiding a vehicle making an illegal U-turn on KY 269. Of the seven before accidents, six could be somewhat related to poor sight distance. Four accidents, including the fatality, were directly related to bad sight distance on the accident reports. One unrelated accident resulted from a truck losing a tire. Increasing the sight distance was obviously successful as illustrated by the collision diagram. The stop bar was helpful in encouraging drivers to stop at a location where sight distance was best.

The cost of improvement was $650. The direct accident savings was $21,715 and resulted in a benefit-cost ratio of 33.4.



OHIO COUNTY

US 231 AT MP 5.6



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